# Manufacturing Advantage Service

## Manufacturing With Intel® Wave Solder Heatsink (Intel® WSHS)

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  - to reduce **C**ustomer **L**ine **F**allout (CLF) ✍ equating to higher 1st pass line yields, reduce **C**ustomer **I**nduced **D**amage (CID) returns and reduce **N**o **D**efect **F**ound (NDF) returns.
- This material is not designed to present detailed technical information or specifications, but to share experiences that can be utilized in customer manufacturing enabling.

# Session Agenda

- Introduction
- Intel® WSHS  Process Overview / Considerations
- Manufacturing Considerations
- Manufacturing with the Intel® WSHS
- Intel® WSHS  Removal and Installation Procedure
- Backup
  - Acronyms and Definitions
  - Reference Documents
  - Thermal Metrology
  - Sample Mechanical Drawings on Springdale-G Keep-Out Zone
  - Dwell Time Measurement Using Glass Plate

# Introduction

- The objective of thermal management is to ensure that the temperature of all components in a system are maintained within functional limits.
- The functional temperature limit is the range within which the electrical circuits can be expected to meet specified performance requirements.
- Operation outside the functional limit can degrade system performance, cause logic errors, or cause component and/or system damage.
- Temperatures exceeding the maximum operating limits may result in irreversible changes in the operating characteristics of the component.

# Introduction:
# Reference Thermal Solution

- The Intel® Wave Solder Heatsink (Intel® WSHS ) is the reference component thermal solution for the Springdale GMCH.  The following provides detailed information on operating environment assumptions, heatsink installation, heatsink rework, and mechanical reliability requirements.

# Introduction: Operating Environment

- To ensure proper operation and reliability of the GMCH, an airflow speed of 0.25 m/s [50 lfm] is assumed to be present 25 mm [1 in] in front of the heatsink air inlet side of the attached reference thermal solution.
- Furthermore, the maximum allowable operating air temperature at the GMCH heatsink is assumed not exceed 50 degree C.
- The thermal designer must carefully select the location to measure airflow to get a representative sampling. These environmental specifications are based on a 35 degree C system external temperature measured at 1524 m [5000 ft].

# Introduction:
# Mechanical Design Envelope

- The motherboard component keep-out restrictions for the Intel® WSHS  are included in Figure 12, in the Mechanical Drawing section of the the backup material.
- The Intel® WSHS  extends 38.2 mm [1.5 in] nominally above the board when mounted.
- System integrators should ensure no board or chassis components will intrude into the volume occupied by the Intel® WSHS .

# Intel® WSHS Process Overview / Considerations

# Big Picture Overview

- There are two key items to a successful Intel® WSHS installation process:
  - Prevention of gross tilt
    - » Critical to ensure good Thermal Interface Material (TIM) to package contact and good time zero thermal performance
  - Formation of good solder joints
    - » Critical for mechanical integrity to survive reliability testing
      - ¤ Shock and vibration testing
      - ¤ Temperature cycling

# Critical Factors for Tilt Prevention

- The Printed Circuit Board (PCB) will typically sag during the wave process primarily due to thermal expansion mismatch between the top and bottom of the PCB
  - The wave solder heat sink must be allowed to move with the board during the dynamic event
  - Trying the “fix” the position of the Intel® WSHS  using a top hat fixture will typically result in worse tilt than a free floating Intel® WSHS

# Critical Factors for Good Solder Joint Formation

- Good solder joint formation is dependent upon a large number of factors
  - The primary difference between the solder joint formation for the Intel® WSHS and a typical through-hole mount (THM) component is the temperature of the pin.
  - The Intel® WSHS (by design) will cool the pin much more rapidly than typical THM components. Therefore, to compensate for this, key process parameters have been identified (next foil).

# Critical Intel® WSHS Factors

- Dwell time is a minimum of 2.1 seconds
- Preheat must ensure the PCB is a minimum of 90 degree C leaving the last preheat zone
- The above two criteria are based on 0.062” thick desktop form factor PCBs using standard wave pallets
  - Masked pallets have never been used with Intel® WSHS and are known to impact heat transfer into the PCB during preheat, particularly for bottom side infrared preheat.

# Manufacturing Considerations

# Thermal Solution Assembly

- The reference thermal solution consists of a passively cooled Intel® WSHS .
- The heatsink is comprised of an extruded aluminum heatsink with four mounting pins pressed into each corner of the heatsink base.
- A thermal interface material (Chomerics* T-710) is pre-applied to the heatsink bottom over an area in contact with the package die.
- A 45 degree dado cut is performed on the heatsink base in order to create rails to reduce the possibility of tilt when assembling the Intel® WSHS .

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# Thermal Solution Assembly

- Since the rails are oriented at 45 degree relative to the heatsink edges, the Intel® WSHS is only compatible with a GMCH rotated 45 degree relative to the motherboard.
- Foil 18 describes an alternate Intel® WSHS design that is compatible with a GMCH that is not rotated relative to the motherboard.
- **Note:** the rails do not touch the package substrate in the nominal position.
- The Intel® WSHS is shown in the installed configuration in Figure 1 (the GMCH cannot be seen in this view as it is hidden by the Intel® WSHS base).

# Thermal Solution Assembly

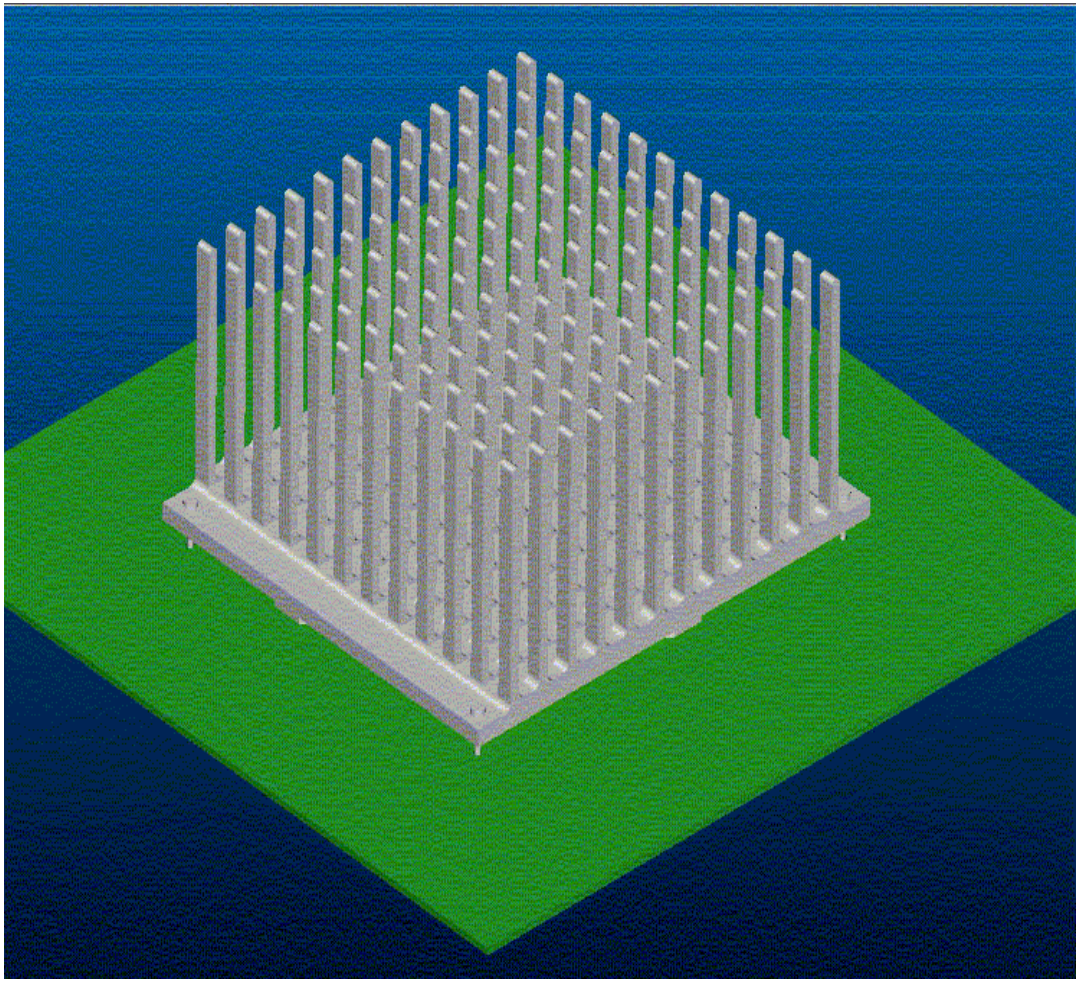


Figure 1. Intel® Wave Solder Heatsink Installed on Board

# Alternate Intel® WSHS for Non-Rotated GMCH

- The Intel® WSHS can be modified into an alternate configuration for a non-rotated GMCH.
- Customers that wish to develop an alternate design should work with licensed suppliers and implement the following recommendations:
  - 1. Create an extrusion die that will create two parallel rails matching the rails on the underside of the heatsink, but at a 0 degree rotation relative to the heatsink.
  - 2. Omit the dado cut from the manufacturing process.

# Manufacturing with the Intel® WSHS

# Assembly Process Settings

| Setting | Minimum | Maximum | Notes |
|---|---|---|---|
| Board Temperature on Preheat Region Exit | 90 degree C [194 degree F] | 120 degree C [248 degree F] | Recommend not exceeding 120 degree C [248 degree F] due to flux dry out |
| Dwell Time (see Dwell Time Measurement Using Glass Plate in Back Up Section) | 2.1 sec | As Required | Not to exceed 160 degree C [320 degree F] board topside temperature |
| Solder Bath Temperature | 240 degree C [464 degree F] | As Required | Not to exceed 160 degree C [320 degree F] board topside temperature using the minimum dwell time |

Table1. Wave Solder Recommended Settings for Intel® WSHS

# Typical Intel® WSHS Wave Profile

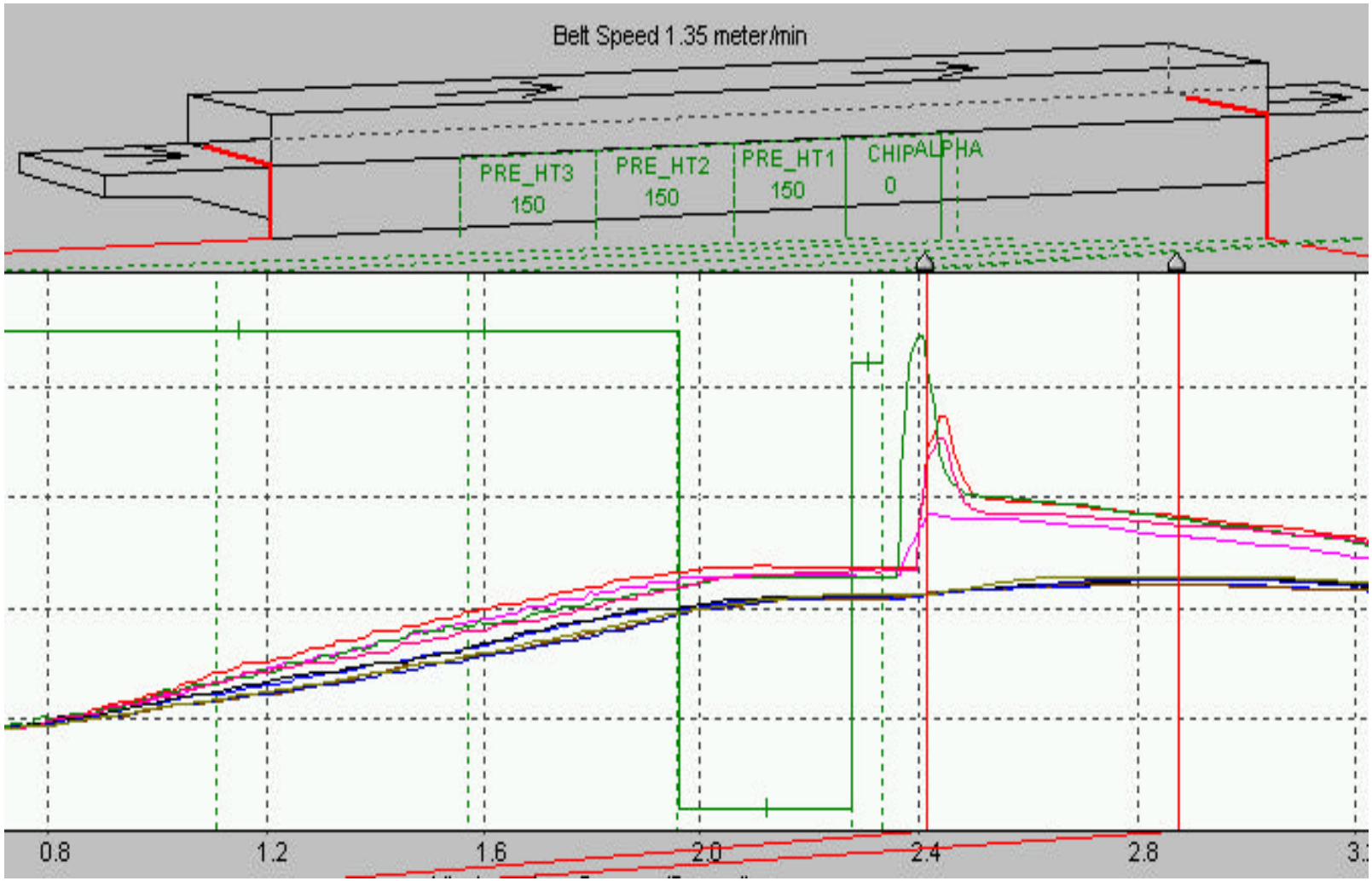



Figure 2. Typical Intel® WSHS Wave Profile

# Assembly Process Settings

- In addition to the information in Table 1, the recommended solder type is standard eutectic 63/37 Sn/Pb.
- No “top hat” plungers should be used to hold down the Intel® WSHS during the wave solder process since it may increase the risk of heatsink tilt.
- For best results the Intel® WSHS should be left in a “floating” condition as it passes through the wave solder.

# Post Wave Solder Tilt Inspection Criteria

- After the Intel® WSHS is installed and exits the wave solder process, it should be visually inspected to ensure there are no gross tilt issues.
  - Any gross tilt in the Intel® WSHS will impact the thermal performance of the heatsink.
  - The degree of allowable tilt is set to ensure no TIM gap is present post assembly (100% TIM coverage)
  - This amount of gap is easily detectable by trained inspectors. Gross tilt inspection results can allow for closer inspection and measurement of tilt. Only “suspiciously tilted” Intel® WSHS would be measured; the vast majority of Intel® WSHS would not be measured.

# Gross Tilt Definition

- The definition of gross tilt is a difference of 14 mils or more between the pin gap on opposite sides
  - Nominal pin gap is 86 mils; a 14 mil gap translates to a ~16% difference in gap
    - » Typical values for difference in gap are 0-5 mils (mean 1.5 mils, std dev 1.6 mils)
  - This difference in gap is easily detectable by a trained operator
  - The gap can reference the corners of a 45 degree rotated SDG package (package gap instead of pin gap). Due to the smaller nominal gap (33 mils), this 14 mil difference is even more pronounced (~42%) and even easier to see

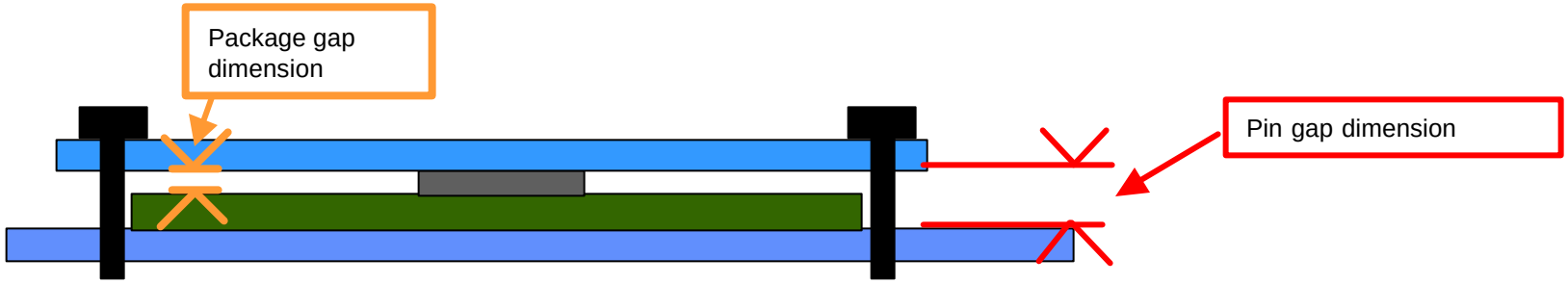



Figure 5. Pin Gap Gross Tilt Definition

# Inspection Criteria

Minimum of 75% solder coverage on pad and lead on the secondary side.

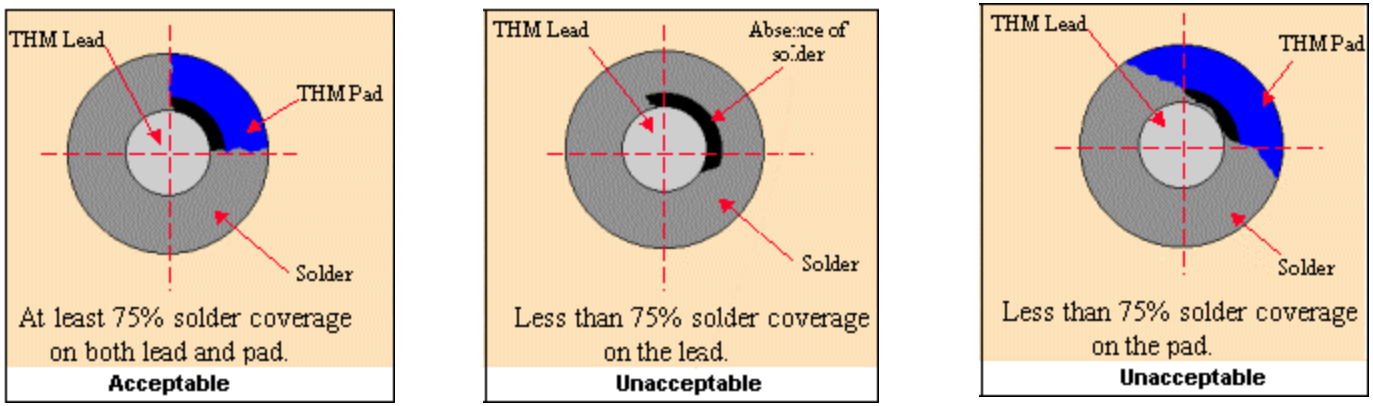



Figure 3. Wetting, Hole Fill, and Fillet Minimum Requirements

# Advanced Visual Criteria (not HVM)

Primary Side Wetting Angle:

- Wetting angle requirement: < 90 degrees on at least one of the two angles present in a cross section (wetting angle shown in red)
- (Ideal < 30 degrees)

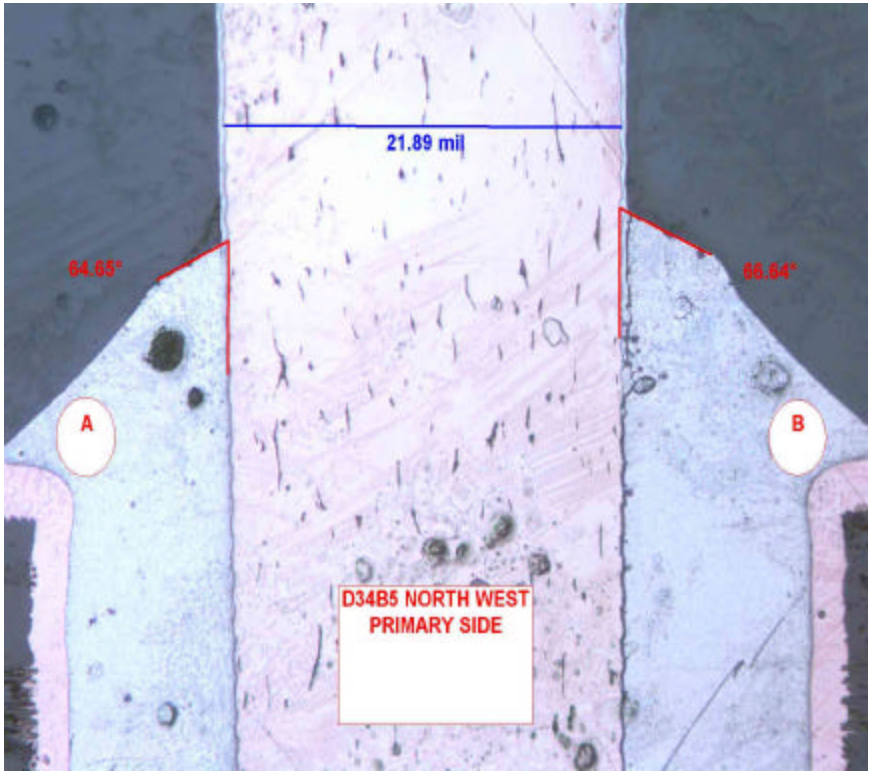



Figure 4. Wetting angle was measured using OM

# Intel® WSHS Removal and Installation Procedure

# Intel® WSHS Removal and Installation Procedure

Two methods exist for Intel® WSHS removal, lead clipping or de-soldering. Re-installation of the heatsink for rework or metrology purposes includes a single method.

- Removal via Lead Clipping Methodology
- Removal via De-Soldering Methodology

# Removal via Lead Clipping Methodology

- Recommended equipment list:
  1. 55 degree angle clippers (Figure 6)
  2. Solder wicking kit

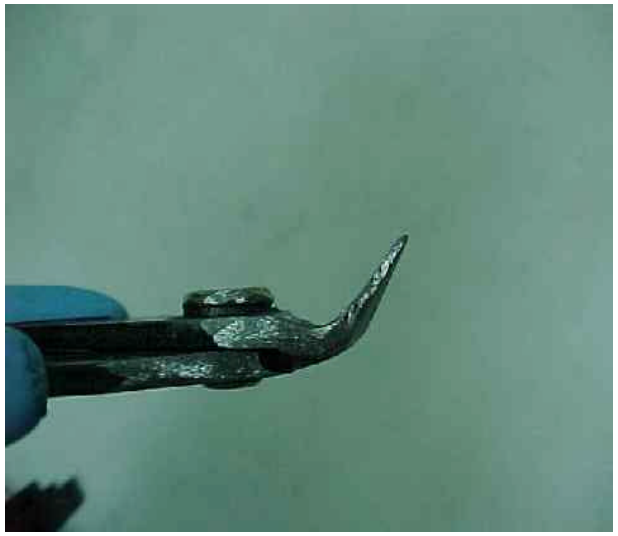


Figure 6. 55 degree Angle Clippers

# Removal via Lead Clipping Methodology

- Removal Procedure

1. Remove any neighboring obstructions that restrict access to the Intel® Wave Solder Heatsink THM pin(s). For Springdale G this will include the processor heatsink retention mechanism.

2. Cut the Intel® WSHS leads using the 55 degree angle clippers. To reduce the potential of damaging motherboard and components, cut the leads in the order shown in Figure 7.

3. Flip the board over and remove the leads, using tweezers and a soldering iron with a STTC 137 tip.

4. Apply flux and remove any residual solder from each hole.

5. Inspect the board and ensure all holes are clean and completely free of solder. Make sure none of the adjacent components were damaged during the removal process.

# Removal via Lead Clipping Methodology

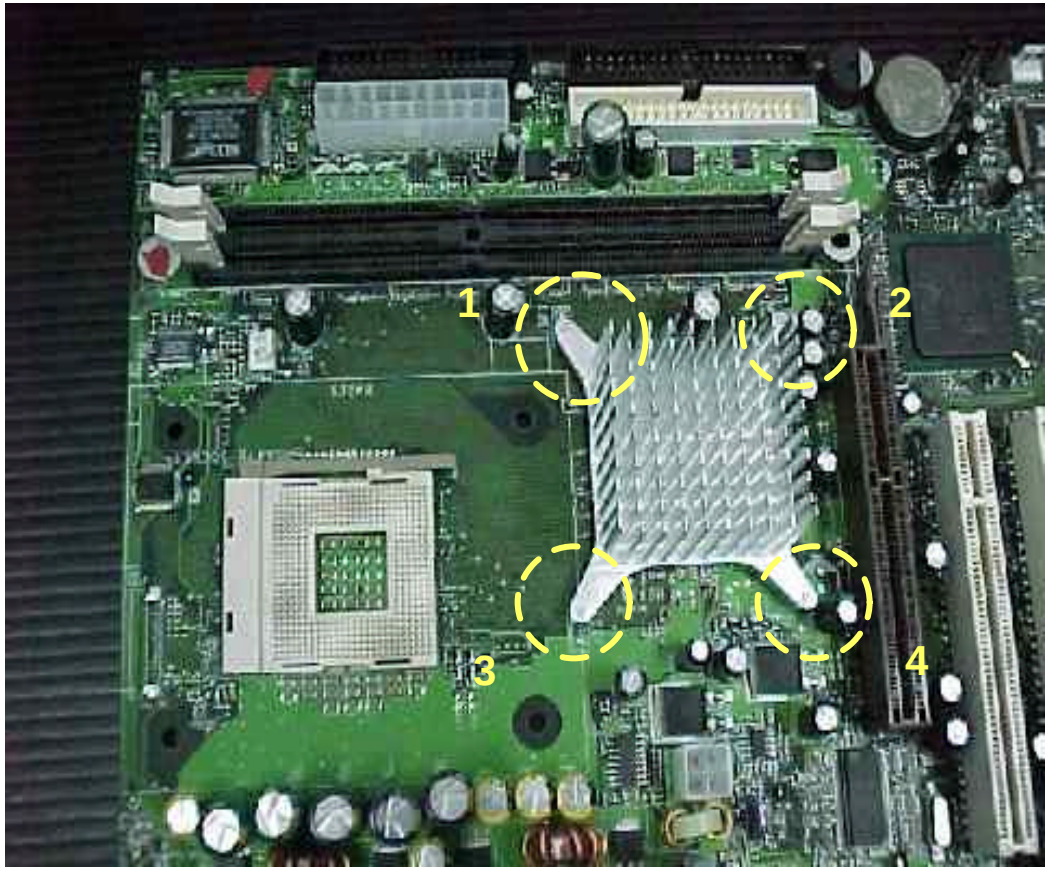



Figure 7. Intel® WSHS Lead Clipping Order

# Removal via De-Soldering Methodology

- Recommended equipment list:

1. De-soldering gun
2. Solder wicking kit
3. Vertical work jig (Figure 8)

# Removal via De-Soldering Methodology

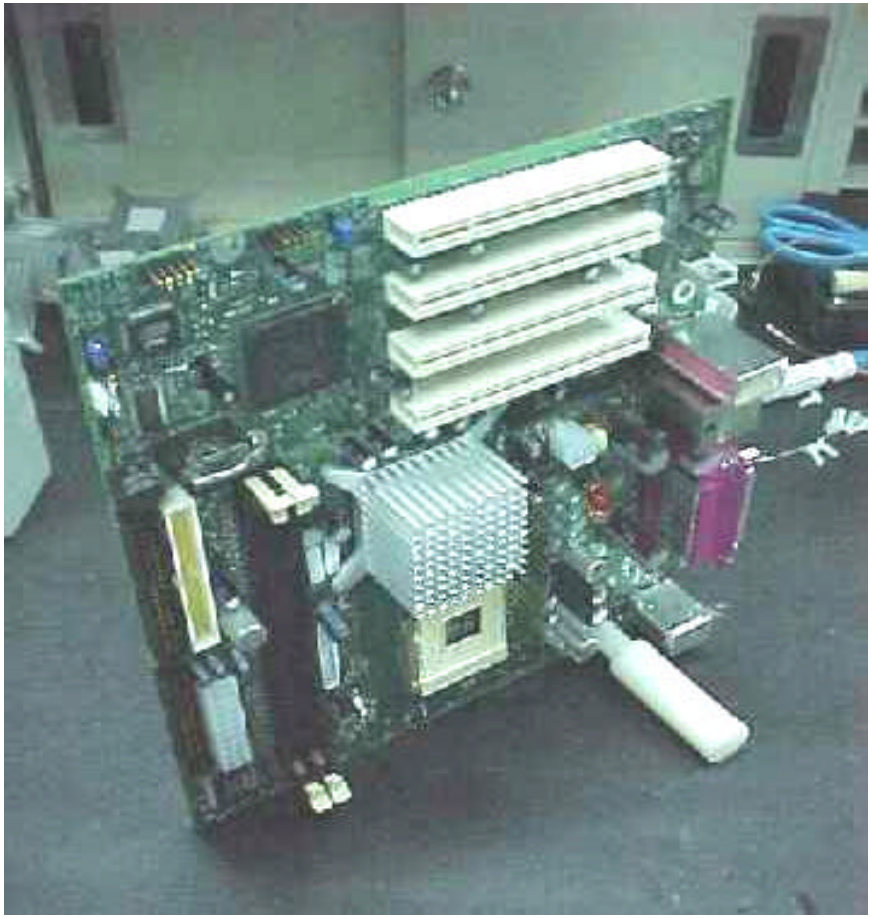


Figure 8. Example Vertical Rework Jig

# Removal via De-Soldering Methodology

- Removal procedure:
  1. Remove processor heatsink retention mechanism.
  2. De-solder the Intel® WSHS leads using a SMTC 104 tip. Use a small amount of solder to prime the tip if necessary.
  3. Stand the board vertically using jig (Figure 8).
  4. Use a soldering iron with an STTC 137 tip to loosen Intel® WSHS pins and remove the heatsink. Gently wiggle each lead loose while applying heat to lead.
  5. Apply flux and remove any residual solder from each hole.
  6. Inspect the board and ensure all holes are clean and completely free of solder. Make sure none of the adjacent components were damaged during the removal process.
- Inspect the board and ensure all holes are clean and completely free of solder. Make sure none of the adjacent components were damaged during the removal process.

# Re-Installation Methodology

- Recommended equipment:

  1. Intel® WSHS  rework target (Figure 9)
  2. SMT rework tool such as an SRT 1000 or 1100

# Re-Installation Methodology

- Installation procedure:

1. Insert Intel® WSHS into board. Avoid scratching the board as the pins are placed into the mounting holes.
2. Ensure the Intel® WSHS "floats" on top of the GMCH. The Intel® WSHS should move freely. If it does not "float", remove any residual solder that may be in the mounting holes.
3. Place the Intel® WSHS target on top of the Intel® WSHS fins.
4. Use the SMT rework tool to melt the TIM. Use 145 grams placement force and set the bottom temperature to 220 degree C (428 degree F) for 90 seconds duration.

# Re-Installation Methodology

6. Cool the board to room temperature.

7. Stand the board vertically using jig.

8. Solder the Intel® WSHS leads using a soldering iron with a STTC 137 tip.

# Re-Installation Methodology



Figure 9. Intel® WSHS Target

# Environmental Reliability Requirements

- The environmental reliability requirements for the reference thermal solution are shown in Table 2.
- These should be considered as general guidelines. Validation test plans should be defined by the user based on anticipated use conditions and resulting reliability requirements.

# Environmental Reliability Requirements

| Test[1] | Requirement | Pass/Fail Criteria[2] |
|---|---|---|
| Mechanical Shock | · Quantity: 3 drops for + and - directions in each of 3 perpendicular axes (i.e., total 18 drops).<br>· Profile: 50 G trapezoidal waveform, 11 ms duration, 4.3 m/s [170 in/s] minimum velocity change.<br>· Setup: Mount sample board on test fixture. Include 450 g processor heatsink. | Visual\Electrical Check |
| Random Vibration | · Duration: 10 min/axis, 3 axes<br>· Frequency Range: 5 Hz to 500 Hz<br>· Power Spectral Density (PSD) Profile: 3.13 g RMS | Visual/Electrical Check |
| Thermal Cycling | · -40 degree C to +85 degree C, for reference Intel uses 686 cycles (number of actual cycles depends on the user conditions) | Visual Check |
| Temperature Life | · 85 degree C, 1000 hours total | Visual/Electrical Check |
| Unbiased Humidity | · 85 % relative humidity / 130 degree C, 100 hours | Visual Check |

1. The above tests should be performed on a sample size of at least 12 assemblies from 3 different lots of material.
2. Additional Pass/Fail Criteria may be added at the discretion of the user.

Table 2. Reference Thermal Solution Environmental Reliability Requirements

# Backup

# Acronyms and Terminology

| Term | Description |
|---|---|
| BGA | Ball Grid Array. A package type defined by a resin-fiber substrate where a die is mounted, bonded and encapsulated in molding compound. The primary electrical interface is an array of solder balls attached to the substrate opposite the die and molding compound. |
| FC-BGA | Flip Chip Ball Grid Array. A package type defined by a plastic substrate where a die is mounted using an under fill C4 (Controlled Collapse Chip Connection) attach style. The primary electrical interface is an array of solder balls attached to the substrate opposite the die. Note that the device arrives at the customer with solder balls attached. |
| Intel® ICH5 | Intel® I/O Controller Hub 5. The chipset component that contains the primary PCI interface, LPC interface, USB, ATA, and/or other legacy functions. |
| MBGA | Mini Ball Grid Array. A smaller version of the BGA with a ball pitch of 1.00 mm [0.039 in]. |
| GMCH | Graphic Memory Controller Hub. The chipset component that contains the processor and memory interface and integrated graphics core. |
| $T_A$ | The measured ambient temperature locally to the component of interest. The ambient temperature should be measured just upstream of airflow for a passive heatsink or at the fan inlet for an active heatsink. |
| $T_C$ | The measured case temperature of a component. For processors, it is measured at the geometric center of the integrated heat spreader (IHS). For other component types, it is generally measured at the geometric center of the die or case. |

# Acronyms and Terminology

| | |
|---|---|
| $T_{C\text{-}MAX}$ | The maximum case/die temperature with an attached heatsink. This temperature is measured at the geometric center of the top of the package case/die. |
| $T_{C\text{-}MIN}$ | The minimum case/die temperature with an attached heatsink. This temperature is measured at the geometric center of the top of the package case/die. |
| TDP | Thermal Design Power is specified as the highest sustainable power level of most or all of the real applications expected to be run on the given product, based on extrapolations in both hardware and software technology over the life of the component. Thermal solutions should be designed to dissipate this target power level. |
| TIM | Thermal Interface Material: thermally conductive material installed between two surfaces to improve heat transfer and reduce interface contact resistance. |
| lfm | Linear Feet per Minute. Unit of airflow speed. |
| $Y_{CA}$ | Case-to-ambient thermal characterization parameter (Psi). A measure of thermal solution performance using total package power. Defined as $(T_C - T_A)$ / Total Package Power. Heat source should always be specified for Y measurements. |
| Intel® WSHS | Intel® Wave Solder Heatsink. A heatsink that is installed to a motherboard via wave solder process. Pins are fixed to the heatsink base and are held in place by solder. There are no associated retention clips or retention anchors. |

# Reference Documents

| |
|---|
| *Springdale GMCH External Design Specification (EDS)* |
| *Springdale GMCH External Design Specification Addendum (EDS Addendum)* |
| *Intel® I/O Controller Hub 5 (ICH5) Thermal Design Guidelines* |
| *Intel® Pentium® 4 Processor in the 478 Pin Package / Prescott Processor and Springdale Chipset Platform Design Guide* |
| *Prescott Processor Electrical, Mechanical, and Thermal Specifications (EMTS)* |
| *Prescott Processor Thermal Design Guidelines* |
| *Various System Thermal Design Suggestions (http://www.formfactors.org)* |

- The following information can be found in the *Springdale Chipset GMCH Thermal and Mechanical Design Guidelines:*
  - –Springdale thermal specifications
  - –Thermal metrology
  - –Thermal test tools
- **Please contact your Local Field Sales or Field Applications Engineer for document ordering information**

# Thermal Metrology

- The system designer must measure temperatures in order to accurately determine the thermal performance of the system.  Intel has established guidelines for proper techniques of measuring chipset component case temperatures.

# Case Temperature Measurements

- To ensure functionality and reliability, the chipset GMCH is specified for proper operation when $T_C$ is maintained at or below the maximum temperature listed in Table 3. The surface temperature at the geometric center of the die corresponds to $T_C$. Measuring $T_C$ requires special care to ensure an accurate temperature measurement.

| Parameter | Value |
|---|---|
| $T_{C\text{-}MAX}$ | See Product Specific Reference Thermal and Mechanical Design Guidelines (foil 44) |
| $T_{C\text{-}MIN}$ | See Product Specific Reference Thermal and Mechanical Design Guidelines (foil 44) |

Table 3. Example of Case Temperature Specifications

# Case Temperature Measurements

- Temperature differences between the temperature of a surface and the surrounding local ambient air can introduce error in the measurements.
- The measurement errors could be due to a poor thermal contact between the thermocouple junction and the surface of the package, heat loss by radiation and/or convection, conduction through thermocouple leads, or contact between the thermocouple cement and the heatsink base (if a heatsink is used).
- To minimize these measurement errors, two approaches are recommended for thermocouple attach, with the zero degree angle attach being the preferred method.

# Case Temperature Measurements

- Although the basic metrology is the same for a clip-attached heatsink and a Intel® Wave Solder Heatsink, the removal and replacement of the Intel® WSHS requires additional guidelines for accurate thermal measurements.
- Refer to the Intel® WSHS rework procedure found in foils 29-40 for guidelines on installing a Intel® WSHS modified for a zero degree attach. Physical modifications to a Intel® WSHS are identical to modifications for a clip-attached heatsink.
- Foils 49-51 detail the modifications required to measure package case temperature using both clip-attached heatsinks and Intel® WSHS .

# 0 Degree Angle Attach Methodology (Recommended)

1. Mill a 3.3 mm [0.13 in] diameter hole centered on bottom of the heatsink base. The milled hole should be approximately 1.5 mm [0.06 in] deep.
2. Mill a 1.3 mm [0.05 in] wide slot, 0.5 mm [0.02 in] deep, from the centered hole to one edge of the heatsink. The slot should be in the direction parallel to the heatsink fins (see Figure 11).
3. Attach thermal interface material (TIM) to the bottom of the heatsink base.
4. Cut out portions of the TIM to make room for the thermocouple wire and bead. The cutouts should match the slot and hole milled into the heatsink base.

# 0 Degree Angle Attach Methodology (Recommended)

5. Attach a 36 gauge or smaller calibrated K-type thermocouple bead or junction to the center of the top surface of the die using a high thermal conductivity cement. During this step, make sure no contact is present between the thermocouple cement and the heatsink base because any contact will affect the thermocouple reading. **It is critical that the thermocouple bead makes contact with the die** (see Figure 10).

# 0 Degree Angle Attach Methodology (Recommended)

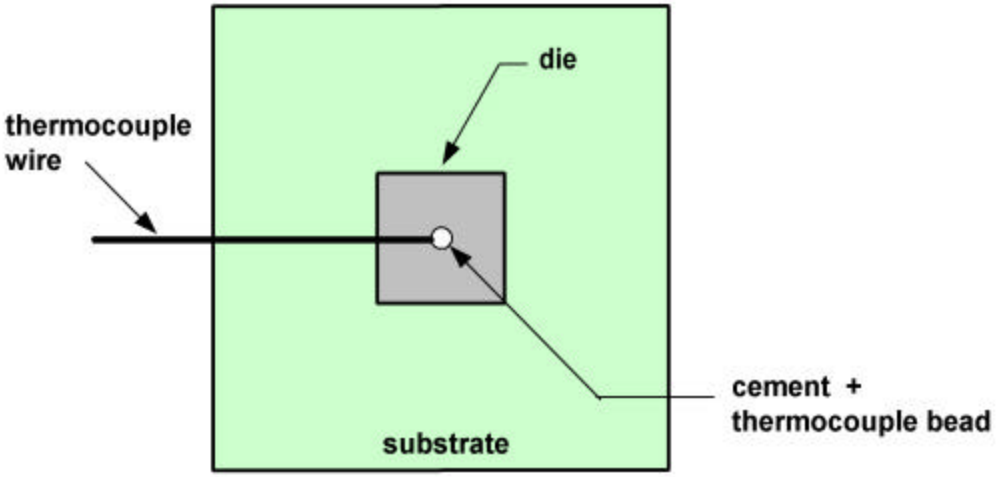



Figure 10. 0 degree Angle Attach Methodology (top view, not to scale)

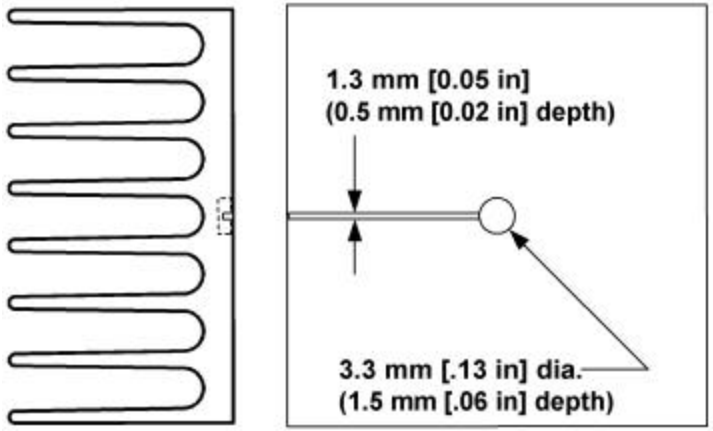



Figure 11. 0 degree Angle Attach Heatsink Modifications (not to scale)

# Springdale - G

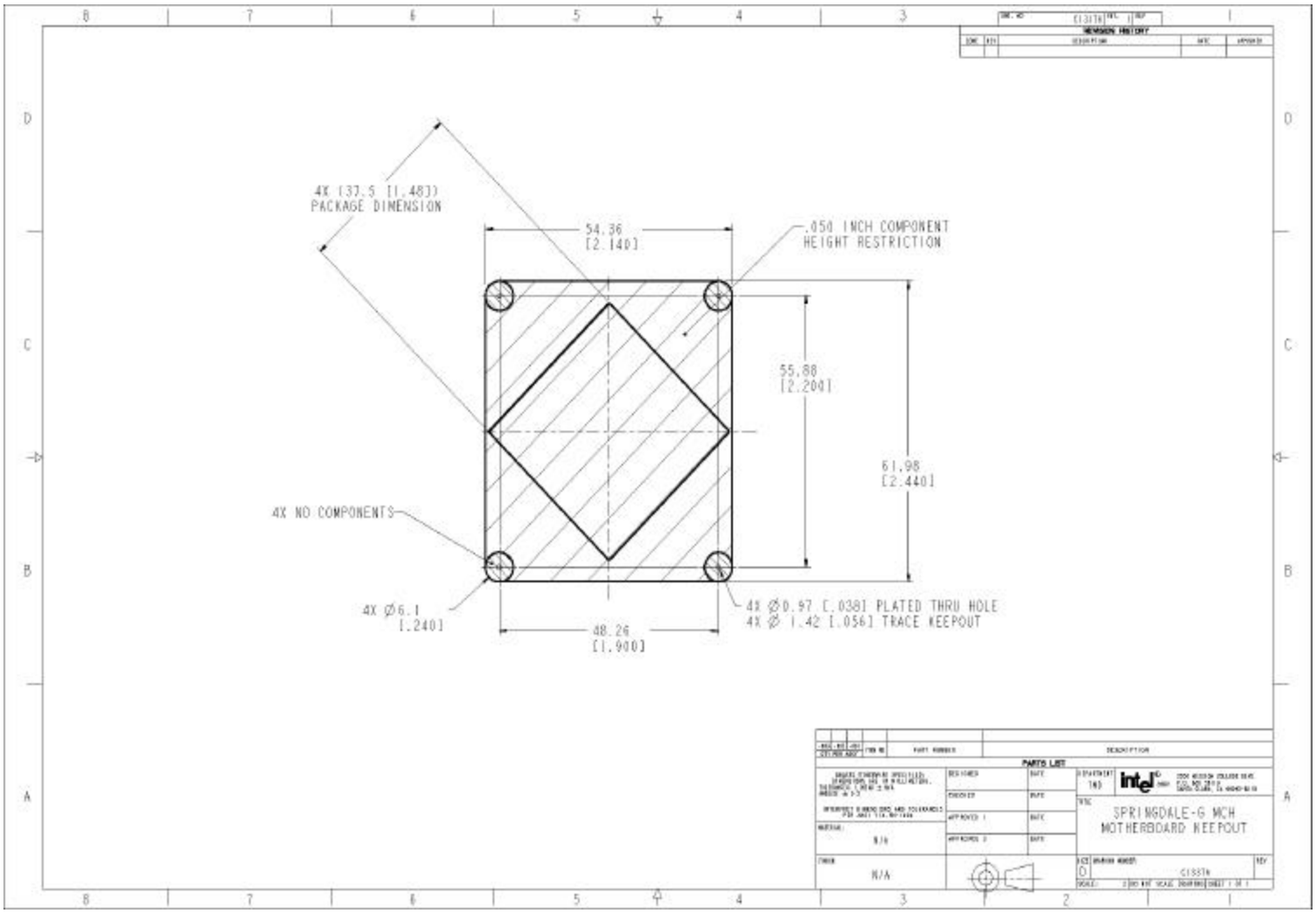



Figure 12. Springdale-G Component Keep-Out Area

# Dwell Time Measurement Using Glass Plate

**Reference Figure 14**

- Materials:
  - Wave solder fixture that sets a glass plate at the same relative distance from wave solder as the product fixtures hold the PCB. ***This is critical***
  - Glass plate that fits into the wave solder fixture described above.
  - Calipers.

# Dwell Time Measurement Using Glass Plate

- Process:
  - Apply a line along the conveyed edge of the glass plate 1” from each edge.
  - Run Glass plate in wave solder fixture into oven using the wave profile and wave settings used for product. Ensure fluxer is running.
  - Stop the conveyor when the main wave contact is approximately in the center of the glass plate.
  - Measure the length of wave contact (in inches) at the right and left side using calipers and the lines 1” from each edge of the glass plate as the point of measurement.
  - Convert conveyor speed from meters per minute to inches per second (Conveyor speed * 39.369 / 60)
  - Calculate left and right side dwell time (contact length / inches per second)

# Dwell Time Measurement Using Glass Plate

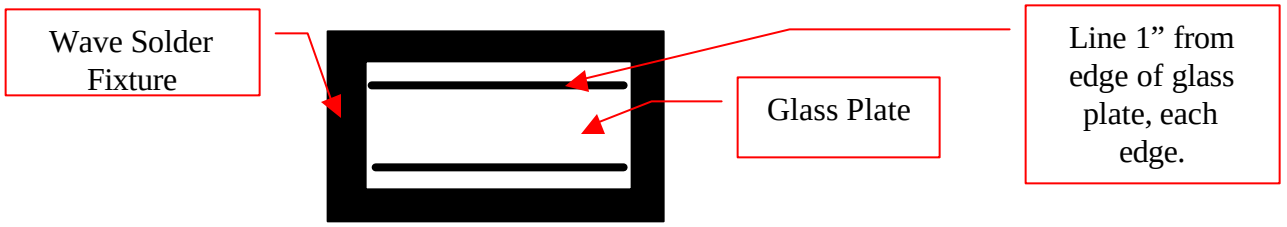



Figure 13. Wave Solder Set-Up for Dwell Time Measurement Using Glass Plate

Requirements:

1. No more than .3 seconds difference in dwell time from right to left side.
2. Minimum of 2.1 seconds of dwell time for either side.

# Enabled Suppliers

| Supplier | Intel P/N | Supplier P/N | Contact Information |
|---|---|---|---|
| CCI | C19335 | 00C852301A | **Monica Chih**<br>**12/F, 123-1, Hsing De Road**<br>**San Chung Taipei, Taiwan, R.O.C.**<br>**Taiwan**<br>**Phone: +886 - 2 2-995-2666 Ext 131**<br>**Fax: 011 – 886-2 299-58258**<br>**monica_chih@ccic.com.tw** |
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Table 4. Heatsink Enabled Suppliers